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Philosophical Transactions

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XXXIX. *Of the electric Property of the Torpedo. In a Letter from John Walsh, Esq; F. R. S. to Benjamin Franklin, Esq; LL. D., F. R. S., Ac. R. Par. Soc. Ext., &c.*

Chesterfield-Street, July 1, 1773.

DEAR SIR,

Read July 1, 1773. **I** Am concerned that other engagements have prevented me from giving to the Royal Society, before their recess, a complete account of my experiments on the electricity of the Torpedo; a subject not only curious in itself, but opening a large field for interesting inquiry, both to the electrician in his walk of physics, and to all who consider, particularly or generally, the animal oeconomy.

To supply the deficiency in the best manner I am now able, I will request the favour of you to lay before the Society my letter from la Rochelle, of the 12th July 1772, and such part of the letter I afterwards wrote from Paris, as relates to this subject. Loose and imperfect as these informations are, for they were never intended for the public eye, they are still the most authentic, and so far the most

satisfactory I can at present offer, since the notes I made of the experiments themselves remain nearly, I am sorry to say it, in that crude and bulky state in which you had the trouble to read them.

Letter from Mr. WALSH to Dr. FRANKLIN, dated
la Rochelle, 12th July 1772.

“ It is with particular satisfaction I make to you
“ my first communication, that the effect of the
“ Torpedo appears to be absolutely electrical; by
“ forming its circuit through the same conductors
“ with electricity, for instance metals, and water;
“ and by being intercepted by the same non-con-
“ ductors, for instance glass, and sealing-wax. I
“ will not at present trouble you with the detail of
“ our experiments, especially as we are daily ad-
“ vancing in them; but only observe, that we have
“ discovered the back and breast of the animal to be
“ in different states of electricity: I mean in par-
“ ticular the upper and lower surfaces of those two
“ assemblages of pliant cylinders, of which you
“ have seen engravings in Lorenzini *. By the
“ knowledge of this circumstance we have been
“ able to direct his shocks, though they were very
“ small, through a circuit of four persons, all feel-
“ ing them; likewise through a considerable length
“ of wire held by two insulated persons, one touching
“ his lower surface, and the other his upper. When

* Osservazioni intorno alle Torpedini di Stef. Lorenzini
1678.

Redi appears to be the first who remarked these singular parts
of the Torpedo in 1666. Franc. Redi, Exper. Nat.

“ the

“ the wire was exchanged for glass, or sealing-wax,
 “ no effect could be obtained : but as soon as it was
 “ resumed, the two persons became liable to the
 “ shock. These experiments have been varied many
 “ ways, and repeated times without number, and
 “ they all determined the choice of conductors
 “ to be the same in the Torpedo as in the Ley-
 “ den Phial. The sensations likewise, occasioned
 “ by the one and the other in the human frame, are
 “ precisely similar. Not only the shock, but the
 “ numbing sensation which the animal sometimes
 “ dispenses, expressed in French by the words *en-*
 “ *gourdissement* and *fourmillement*, may be exactly imi-
 “ rated with the Phial, by means of Lane’s Electro-
 “ meter ; the regulating rod of which, to produce the
 “ latter effect, must be brought almost into contact
 “ with the prime conductor which joins the Phial.
 “ We have not yet perceived any spark to accompany
 “ the shock, nor the pith balls to be ever affected.
 “ Indeed all our trials have been on very feeble
 “ subjects, whose shock was seldom sensible beyond
 “ the touching finger : I remember but one, of at
 “ least two hundred, that I myself must have re-
 “ ceived, to have extended above the elbow. Per-
 “ haps the Isle of Ré, which we are about to visit,
 “ may furnish us with Torpedos fresher taken and of
 “ more vigour, by which a farther insight into these
 “ matters may be had. Our experiments have been
 “ chiefly in the air, where the animal was more
 “ open to our examination than in water. It is a
 “ singularity that the Torpedo, when insulated,
 “ should be able to give to us, insulated likewise,
 “ forty or fifty successive shocks from nearly the
 I “ same

“ same part; and these with little, if any diminu-
 “ tion in their force: indeed they were all very
 “ minute. Each effort in the animal to give the
 “ shock is conveniently accompanied with a de-
 “ pression of his eyes, by which even his attempts
 “ to give it to non-conductors can be observed.
 “ The animal, with respect to the rest of his body,
 “ is in a great degree motionless, but not wholly so.
 “ You will please to acquaint Dr. Bancroft, of our
 “ having thus verified his suspicion concerning the
 “ Torpedo *, and make any other communication
 “ of this matter you may judge proper. Here I
 “ shall be glad to excite, as far as I am able, both
 “ electricians and naturalists, to push their inquiries
 “ concerning this extraordinary animal, whilst the
 “ summer affords them the opportunity.”

Extracts of a Letter from Mr. WALSH to Dr.
 FRANKLIN, dated Paris, 27th August, 1772.

——— “ I spent a complete week in my ex-
 “ periments at the Isle of Ré, and had there every
 “ convenience for prosecuting them to their extent,
 “ except that I was restrained by the jealousy of
 “ the government from making them where the
 “ animal was caught. At my return to la Ro-
 “ chelle, I communicated to the members of the
 “ Academy of that place, and to many of the prin-
 “ cipal inhabitants, all that I had observed con-
 “ cerning the Torpedo, in the intention of stirring

* Bancroft's Natural History of Guiana, p. 194.

“ up a spirit of inquiry, both as to its electricity and
 “ general œconomy.

“ The vigour of the fresh taken Tor-
 “ pedos at the Isle of Ré, was not able to force the
 “ torpedinal fluid across the minutest tract of air;
 “ not from one link of a small chain, suspended
 “ freely, to another; not through an almost in-
 “ visible separation, made by the edge of a penknife,
 “ in a slip of tinfoil pasted on sealing-wax. The
 “ spark therefore (of course the attendant snapping
 “ noise) was denied to all our attempts to discover
 “ it, not only in day-light, but in complete dark-
 “ ness. I observed to you, in my last, the singu-
 “ larity of the Torpedo being able, when insulated,
 “ to give to an insulated person a great number of
 “ successive shocks: in this situation I have taken
 “ no less than fifty from him in the space of a
 “ minute and an half. All our experiments con-
 “ firmed, that his electricity was condensed, in
 “ the instant of its explosion, by a sudden energy
 “ of the animal; and as there was no gradual
 “ accumulation, nor retention of it, as in the case
 “ of charged glass, it is not at all surprizing that
 “ no signs of attraction or repulsion were perceived
 “ in the pith balls. In short, the effect of the Tor-
 “ pedo appears to arise from a compressed elastic
 “ fluid, restoring itself to its equilibrium in the same
 “ way, and by the same mediums, as the elastic fluid
 “ compressed in charged glass. The skin of the
 “ animal, bad conductor as it is, seems to be a
 “ better conductor of his electricity, than the
 “ thinnest plate of elastic air. Notwithstanding the
 “ weak spring of the torpedinal electricity, I was
 “ able

“ able, in the public exhibitions of my experiments
 “ at la Rochelle, to convey it through a circuit,
 “ formed from one surface of the animal to the
 “ other, by two long brass wires, and four persons,
 “ which number, at times, was increased even to
 “ eight. The several persons were made to com-
 “ municate with each other, and the two outermost
 “ with the wires, by means of water contained in
 “ basins, properly disposed between them for the
 “ purpose; each person dipping his hands in the
 “ nearest basins, connectively with his neighbour on
 “ either side. —

“ The effect produced by the Torpedo, when
 “ in air, appeared, on many repeated experiments,
 “ to be about four times as strong as when in
 “ water.”

A clear and succinct narrative of what passed at one of the public exhibitions, alluded to in the last letter, appeared in the French Gazette of the 30th October 1772. As it came from a very respectable quarter, not less so from the private character of the gentleman, than from the public offices he held, I must desire leave of the Society to avail myself of such a testimony to the facts I have advanced, by giving a translation of that narrative.

**Extract of a Letter from the Sieur SEIGNETTE,
 Mayor of la Rochelle, and second perpetual
 Secretary of the Academy of that City, to the
 publisher of the French Gazette.**

“ In the Gazette of the 14th August, you men-
 “ tioned the discovery made by Mr. Walsh, Mem-
 “ ber

“ ber of the parliament of England, and of the
 “ Royal Society of London. The experiment, of
 “ which I am going to give you an account, was
 “ made in the presence of the Academy of this
 “ city. A live Torpedo was placed on a table.
 “ Round another table stood five persons insulated.
 “ Two brass wires, each thirteen feet long, were
 “ suspended to the ceiling by silken strings. One
 “ of these wires rested by one end on the wet
 “ napkin on which the fish lay; the other end
 “ was immersed in a basin full of water placed
 “ on the second table, on which stood four other
 “ basins likewise full of water. The first person
 “ put a finger of one hand in the basin in which
 “ the wire was immersed, and a finger of the
 “ other hand in the second basin. The second
 “ person put a finger of one hand in this last
 “ basin, and a finger of the other hand in the
 “ third; and so on successively, till the five per-
 “ sons communicated with one another by the
 “ water in the basins. In the last basin one end
 “ of the second wire was immersed; and with
 “ the other end Mr. Walsh touched the back of
 “ the Torpedo, when the five persons felt a com-
 “ motion which differed in nothing from that of
 “ the Leyden experiment, except in the degree of
 “ force. Mr. Walsh, who was not in the circle
 “ of conduction, received no shock. This expe-
 “ riment was repeated several times, even with
 “ eight persons; and always with the same suc-
 “ cess. The action of the Torpedo is commu-
 “ nicated by the same mediums as that of the
 “ electric fluid. The bodies which intercept the
 Vol. LXIII. P p p “ action

“ action of the one, intercept likewise the action
 “ of the other. The effects produced by the
 “ Torpedo resemble in every respect a weak elec-
 “ tricity.”

This exhibition of the electric powers of the Torpedo, before the Academy of La Rochelle, was at a meeting, held for the purpose in my apartments, on the 22d July 1772, and stands registered in the journals of the Academy.

The effect of the animal was, in these experiments, transmitted through as great an extent and variety of conductors as almost at any time we had been able to obtain it, and the experiments included, nearly, all the points, in which its analogy with the effect of the Leyden Phial had been observed. These points were stated to the gentlemen present, as were the circumstances in which the two effects appeared to vary. It was likewise represented to them, That our experiments had been almost wholly with the animal in air: That its action in water was a capital desideratum: That indeed all as yet done was little more than opening the door to inquiry: That much remained to be examined by the Electrician as well as by the Anatomist: That as artificial electricity had thrown light on the natural operation of the Torpedo, this might in return, if well considered, throw light on artificial electricity, particularly in those respects in which they now seemed to differ: That for me, I was about to take leave of the animal, as nature had denied it to the British seas; and that the prosecution of these researches

rested in a particular manner with them, whose shores abounded with it.

The Torpedo, on this occasion, dispensed only the distinct, instantaneous stroke, so well known by the name of the electric shock. That protracted but lighter sensation, that Torpor or Numbness which he at times induces, and from which he takes his name, was not then experienced from the animal; but it was imitated with artificial electricity, and shewn to be producible by a quick consecution of minute shocks. This, in the Torpedo, may perhaps be effected by the successive discharge of his numerous cylinders, in the nature of a running fire of musketry: the strong single shock may be his general volley. In the continued effect, as well as in the instantaneous, his eyes, usually prominent, are withdrawn into their sockets.

The same experiments, performed with the same Torpedos, were on the two succeeding days repeated before numerous companies of the principal inhabitants of La Rochelle. Besides the pleasure of gratifying the curiosity of such as entertained any on the subject, and the desire I had to excite a prosecution of the inquiry, I certainly wished to give all possible notoriety to facts, which might otherwise be deemed improbable, perhaps by some of the first rank in science. Great authorities had given a sanction to other solutions of the phenomena of the Torpedo; and even the Electrician might not readily listen to assertions, which seemed, in some respects, to combat the general principles of electricity. I had reason to

make such conclusions from different conversations I had held on the subject with eminent persons both at London and Paris. It is but justice to say, that of all in that class you gave me the greatest encouragement to look for success in this research, and even assisted me in forming hypotheses, how the Torpedo, supposed to be endued with electric properties, might use them in so conducting an element as water.

After generally recommending to others an examination of the electric powers of these animals when acting in water, I determined, before I took my final leave of them, to make some farther experiments myself with that particular view ; since, notwithstanding the familiarity in which we may be said to have lived with them for near a month, we had never detected them in the immediate exercise of their electric faculties against other fish, confined with them in the same water, either in the circumstance of attacking their prey, or defending themselves from annoyance : and yet that they possessed such a power, and exercised it in a state of liberty, could not be doubted.

A large Torpedo, very liberal of his shocks, being held with both hands by his electric organs above and below, was briskly plunged into water to the depth of a foot, and instantly raised an equal height into air ; and was thus continually plunged and raised, as quick as possible, for the space of a minute. In the instant his lower surface touched the water in his descent, he always gave a violent shock, and another still more violent in the instant of quitting the water in his ascent ;

ascent ; both which shocks, but particularly the last, were accompanied with a writhing in his body, as if meant to force an escape : Besides these two shocks from the surface of the water, which may yet be considered as delivered in the air, he constantly gave at least two, when wholly in the air, and constantly one and sometimes two, when wholly in the water. The shocks in water appeared, as far as sensation could decide, not to have near a fourth of the force of those at the surface of the water, nor much more than a fourth of those intirely in air.

The shocks received in a certain time were not, on this occasion, counted by a watch, as they had been on a former, when fifty were delivered, in a minute and a half, by the animal in an insulated and unagitated state : But from the quickness, with which the immersions were made, it may be presumed there were full twenty of these in a minute ; from whence the number of shocks, in that time, must have amounted to above an hundred. This experiment, therefore, while it discovered the comparative force between a shock in water and one in air, and between a shock delivered with greater exertion on the part of the animal and one with less, seemed to determine, that the charge of his organs with electricity was effected in an instant, as well as the discharge.

The Torpedo was then put into a flat basket, open at top, but secured by a net with wide meshes, and, in this confinement, was let down into the water, about a foot below the surface ;
being

being there touched, through the meshes, with only a single finger, on one of his electric organs, while the other hand was held, at a distance, in the water, he gave shocks, which were distinctly felt in both hands.

The circuit for the passage of the effect being contracted to the finger and thumb of one hand, applied above and below to a single organ, produced a shock, to our sensation, of twice the force of that in the larger circuit by the arms.

The Torpedo, still confined in the basket, being raised to within three inches of the surface of the water, was there touched with a short iron bolt, which was held, half above and half in the water, by one hand, while the other hand was dipped, as before, at a distance in the water; and strong shocks, felt in both hands, were thus obtained through the iron.

A wet hempen cord being fastened to the iron bolt, was held in the hand above water, while the bolt touched the Torpedo; and shocks were obtained through both those substances.

A less powerful Torpedo, suspended in a small net, being frequently dipped into water and raised again, gave, from the surface of the water, slight shocks through the net to the person holding it.

These experiments in water manifested, That bodies, immersed in that element, might be affected by immediate contact with the Torpedo; That the shorter the circuit in which the electricity

tricity moved, the greater would be the effect; And that the shock was communicable, from the animal in water, to persons in air, through some substances.

How far harpoons and nets, consisting of wood and hemp, could in like circumstances, as it has been frequently asserted, convey the effect, was not so particularly tried as to enable us to confirm it. I mention the omission in the hope that some one may be induced to determine the point by express trial.

We convinced ourselves, on former occasions, that the accurate Kämpfer *, who so well describes the effect of the Torpedo, and happily compares it with lightning, was deceived in the circumstance, that it could be avoided by holding in the breath, which we found no more to prevent the shock of the Torpedo, when he was disposed to give it, than it would prevent the shock of the Leyden Phial.

Several persons, forming as many distinct circuits, can be affected by one stroke of the animal, as well as when joined in a single circuit. For instance, four persons, touching separately his upper and lower surfaces, were all affected; two persons likewise, after the electricity had passed through a wire into a basin of water, transmitted it from thence, in two distinct channels, as their sensation convinced them, into another basin of water, from whence it was conducted, probably in an united state, by a single wire. How

* Kämpfer. *Amer. Exot.* 1712, p. 514.

much further the effect might be thus divided and subdivided into different channels, was not determined; but it was found to be proportionably weakened by multiplying these circuits, as it had been by extending the single circuit.

Something may be expected to be said of the parts of the animal immediately concerned in producing the electrical effect. The engraving, which accompanies this letter, while it shews the general figure of the Torpedo, gives an internal view of his electric organs. The Society will, besides, have a full anatomical description of these parts from the ingenious Mr. John Hunter, in a paper he has expressly written on the subject at my request. It would therefore be superfluous for me to say any thing either in regard to their situation or structure.

I have to observe, however, That in these double organs resides the electricity of the Torpedo, the rest of his body appearing to be no otherwise concerned in his electrical effect than as conducting it: That they are subject to the will of the animal; but whether, like other double parts so controllable, they are exercised, at times, singly as well as in concert, is difficult to be ascertained by experiment: That their upper and under surfaces are capable, from a state of equilibrium with respect to electricity, of being instantly thrown, by a meer energy, into an opposition of a *plus* and *minus* state, like that of the charged Phial: That, when they are thus charged, the upper surfaces of the two are in the same state of electricity; as are the under
surfaces

surfaces of the two, though in a contrary to that of the upper; for no shock can be obtained by an insulated person touching both organs above, or both below: And that the production of the effect depends solely on an intercourse being made between the opposite surfaces of the organs, whether taken singly or jointly.

All the parts bordering on the organs act, more or less, as conductors, either through their substance or by their superficies. While an insulated person, placing two fingers on the same surface of one or both organs, cannot be affected; if he removes one of his fingers to any such contiguous part, he will be liable to a shock: but this shock will not be near, perhaps not half, so violent, as one taken immediately between the opposite surfaces of the organ; which shews the conduction to be very imperfect.

The parts, which conduct the best, are the two great lateral fins bounding the organs outwardly, and the space lying between the two organs inwardly. All below the double transverse cartilages scarcely conduct at all, unless when the fish is just taken out of water and is still wet, the mucus, with which he is lubricated, shewing itself, as it dries, to be of an insulating nature.

The organs themselves, when uncharged, appeared to be, not interiorly we might suppose, but rather exteriorly, conductors of a shock. An insulated person touching two Torpedos, lying near one another on a damp table, with fingers placed, one on the organ of one fish, and another

on the organ of the other, was sensible of shocks, sometimes delivered by one fish, and sometimes by the other, as might be discovered by the respective winking of their eyes. That the organs, uncharged, served some way or other as conductors, was confirmed with artificial electricity, in passing shocks by them; and in taking sparks from them, when electrified.

The electric effect was never perceived by us to be attended with any motion or alteration in the organs themselves, but was frequently accompanied with a little transient agitation along the cartilages which surround both organs: this is not discernible in the plump and turgid state of the animal, while he is fresh and vigorous; but as his force decays, from the relaxation of his muscles, his cartilages appear through the skin, and then the slight action along them is discovered.

May we not from all these premises conclude, that the effect of the Torpedo proceeds from a modification of the electric fluid? The Torpedo resembles the charged Phial in that characteristic point of a reciprocation between its two surfaces. Their effects are transmitted by the same mediums; than which there is not perhaps a surer criterion to determine the identity of subtle matter: They, besides, occasion the same impression on our nerves. Like effects have like causes. But it may be objected, that the effects of the Torpedo, and of the charged Phial, are not similar in all their circumstances; that the charged Phial occasions attractive or repulsive dispositions
in

in neighbouring bodies ; and that its discharge is obtained through a portion of air, and is accompanied with light and sound ; nothing of which occurs with respect to the Torpedo.

The inaction of the electricity of the animal in these particulars, whilst its elastic force is so great as to transmit the effect through an extensive circuit and in its course to communicate a shock, may be a new phænomenon, but is no ways repugnant to the laws of electricity ; for here too, the operations of the animal may be imitated by art.

The same quantity of electric matter, according as it is used in a dense or rare state, will produce the different consequences. For example, a small Phial, whose coated surface measures only six square inches, will, on being highly charged, contain a dense electricity capable of forcing a passage through an inch of air, and afford the phænomena of light, sound, attraction, and repulsion. But if the quantity condensed in this Phial, be made rare by communicating it to three large connected jars, whose coated surfaces shall form together an area 400 times larger than that of the Phial (I instance these jars because they are such as I use) ; it will, thus dilated, yield all the negative phænomena, if I may so call them, of the Torpedo ; it will not now pass the hundredth part of that inch of air, which in its condensed state it sprung through with ease ; it will now refuse the minute intersection in the strip of tinfoil ; the spark and its attendant sound, even the attraction or repulsion of light bodies, will now

be wanting; nor will a point brought however near, if not in contact, be able to draw off the charge: and yet, with this diminished elasticity, the electric matter will, to effect its equilibrium, instantly run through a considerable circuit of different conductors, perfectly continuous, and make us sensible of an impulse in its passage.

Let me here remark, that the sagacity of Mr. Cavendish in devising and his address in executing electrical experiments, led him the first to experience with artificial electricity, that a shock could be received from a charge which was unable to force a passage through the least space of air.

But, after the discovery that a large area of rare electricity would imitate the effect of the Torpedo, it may be inquired, where is this large area to be found in the animal? We here approach to that veil of nature, which man cannot remove. This, however, we know, that from infinite division of parts infinite surface may arise, and even our gross optics tell us, that those singular organs, so often mentioned, consist like our electric batteries of many vessels, call them cylinders or hexagonal prisms, whose superficies taken together furnish a considerable area.

I rejoice in addressing these communications to You. He, who predicted and shewed that electricity wings the formidable bolt of the atmosphere, will hear with attention, that in the deep it speeds an humbler bolt, silent and invisible: He, who analysed the electrified Phial, will hear with
 2. pleasure

pleasure that its laws prevail in animate Phials :
He, who by Reason became an electrician, will
hear with reverence of an instinctive electrician,
gifted in his birth with a wonderful apparatus,
and with the skill to use it.

However I may respect your talents as an electrician, it is certainly for knowledge of more general import, that I am impressed with that high esteem, with which I remain,

Dear Sir,

Your affectionate

and obedient servant,

John Walsh.

EXPLANATION of the PLATE

OF THE

Male and Female Torpedo, or Electric Ray.

T A B. XIX.

F I G. I.

A view of the under surface of the female.

- a.* An exposure, on flaying off the skin, of the right electric organ, which consists of white pliant columns, in a close and for the most part hexagonal arrangement, giving the general appearance of a honey-comb in miniature. These columns have been sometimes denominated cylinders ; but, having no interstices, they are all angular, and chiefly six-cornered.
- b.* The skin which covered the organ, shewing on its inward side an hexagonal net work.
- c.* The nostrils in the form of a crescent.
- d.* The mouth in a crescent contrary to that of the nostrils, furnished with several rows of very small hooked teeth.

e. The

- e.* The branchial apertures, five on each side.
- f.* The place of the heart.
- g. g. g.* The place of the two anterior transverse cartilages, which, passing one above and the other below the spine, support the diaphragm, and uniting towards their extremities, form on either side a kind of clavicle and scapula.
- b. b.* The outward margin of the great lateral fin.
- i. i.* Its inner margin, confining with the electric organ.
- k.* The articulation of the great lateral fin with the scapula.
- l.* The abdomen.
- m. m. m.* The place of the posterior transverse cartilage which is single, united with the spine, and supports on each side the smaller lateral fins.
- n. n.* } The two smaller lateral fins.
- n. n.* }
- o.* The anus.
- p.* The fin of the tail.

FIG. II.

A view of the upper surface of the female.

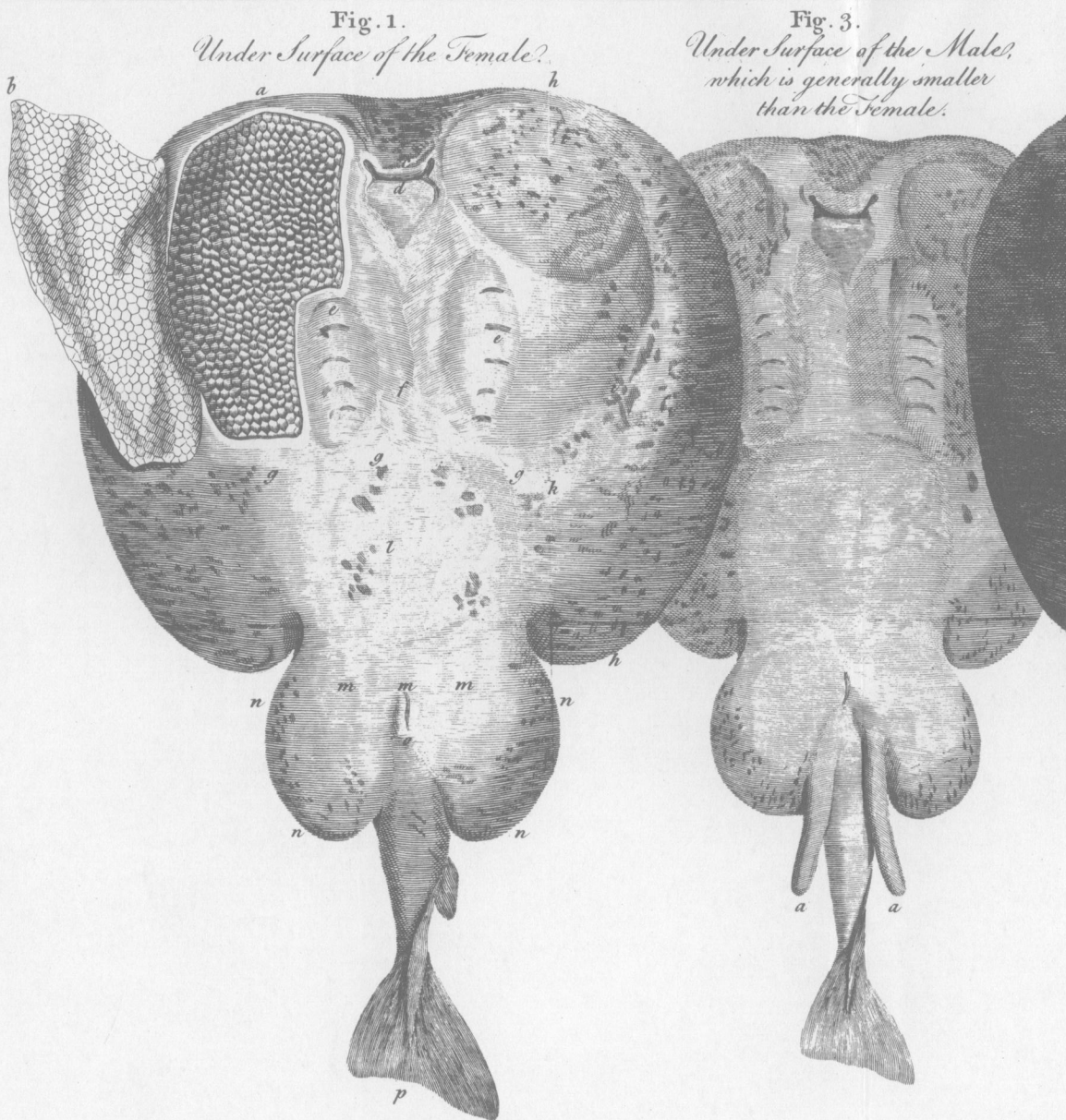
- a. a.* An exposure of the upper part of the right electric organ.
- b.* The skin which covered the organ.
- c.* The eyes, prominent and looking horizontally outwards, but capable of being occasionally withdrawn into their sockets.
- d.* Two circular apertures communicating with the mouth, and furnished each with a membrane, which in air, as well as in water, plays regularly backwards and forwards across the aperture in the office of inspiration.
- e.* The place of the right branchia.
- f.* The two fins of the back.
- g. g.* The place of the anterior transverse cartilages.

FIG. III.

A view of the under surface of the male, whose size, as here represented, is, in general, smaller than that of the female.

- a. a.* Two appendices, distinguishing the male species.

The Male & Female TORPEDO or ELECTROFISH
frequenting the Sea Shores in the Neighbourhood of



Female **TORPEDO** or **ELECTRIC RAY**,
off the Shores in the Neighbourhood of LA ROCHELLE.

Philos. Trans. Vol. LXIII. Tab. XIX. p. 480.

Fig. 3.

*Under Surface of the Male,
which is generally smaller
than the Female.*

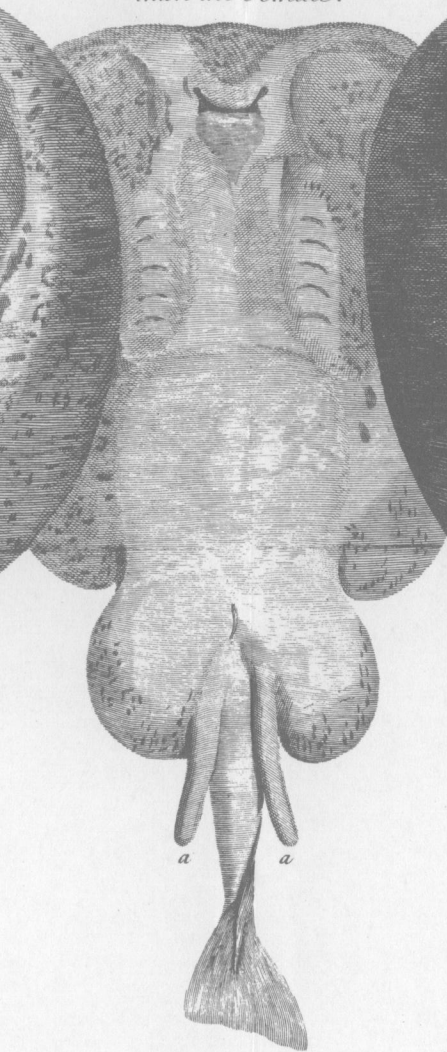


Fig. 2.

Upper Surface of the Female?

